

ORIGINAL ARTICLE

A new termite species of the genus *Dihoplotermes* Araújo (Blattaria, Isoptera, Termitidae) from the Brazilian Amazonian rainforest

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ABSTRACT

Dihoplotermes, a previously monotypic genus, is now composed of two species. *Dihoplotermes taurus* sp. nov., a new Termitinae termite species, is illustrated and described based on morphological characters from soldiers, workers, and imago. The new species is distinguished from *Dihoplotermes inusitatus* Araújo by having a spine-like protuberance with blunt apex on the postmentum, the presence of a spine on the gizzard and the absence of dimorphic soldiers. Furthermore, the internal morphological characteristics of a *Dihoplotermes* worker are described for the first time. Both internal and external morphological characters were used to improve the characterization of the species.

KEYWORDS: gizzard, soil fauna, taxonomy, termite, Termitinae

Uma nova espécie de térmita do gênero *Dihoplotermes* Araújo (Blattaria, Isoptera, Termitidae) da floresta Amazônica Brasileira

RESUMO

Dihoplotermes, que era um gênero monotípico, agora é composto por duas espécies. *Dihoplotermes taurus* sp. nov., uma nova espécie de cupim Termitinae, é descrita e ilustrada com base nos caracteres morfológicos dos soldados, operários e imago. A nova espécie se diferencia de *Dihoplotermes inusitatus* Araújo por apresentar uma protuberância em forma de espinho não pontiagudo no posmento, presença de um espinho na moela e ausência de soldados dimórficos. Além disso, são descritas pela primeira vez as características morfológicas internas de um operário de *Dihoplotermes* e utilizamos ambos caracteres morfológicos internos e externos para melhor caracterizar as espécies.

PALAVRAS-CHAVE: fauna de solo, moela, taxonomia, cupim, Termitinae

INTRODUCTION

Termitinae is a polyphyletic subfamily (Inward *et al.* 2007; Bourguignon *et al.* 2015; Bourguignon *et al.* 2017) belonging to the Termitidae, which is a morphologically diverse group, composed by 661 species described worldwide (Constantino 2018). In the Neotropical Region, five Termitinae genera have soldiers with asymmetrical mandibles. Three genera have the cephalic capsule with a frontal projection (*Cornicapritermes* Emerson, *Dihoplotermes* Araújo, *Palmitermes* Hellems & Roisin), whilst other two genera do not exhibit this feature (*Neocapritermes* Holmgren and *Planicapritermes* Emerson). The presence (in *Dihoplotermes*) or absence (in *Cornicapritermes* and *Palmitermes*) of two anterolateral spines near the base of the mandible distinguishes the first three genera. In *Neocapritermes*, the spine is located dorsally and

only found on the left mandible (Krishna and Araújo 1968). *Dihoplotermes* is more closely related to *Spinitermes* Wasmann and *Cavitermes* Emerson than to other Termitinae genera. This genus shares with *Spinitermes* a conspicuous frontal projection on the top of the head (Inward *et al.* 2007; Bourguignon *et al.* 2017; Hellems *et al.* 2017).

Dihoplotermes was described by Araújo (1961) and revised by Krishna (1968) and Mathews (1977). Until now, *Dihoplotermes inusitatus* Araújo, 1961 was the only species described. The main characteristics of the soldiers belonging to this genus are the presence of spines on the lateral sides of the head near the mandible base, the long, anteriorly pointed conical frontal protuberance on the head, and the asymmetrical mandibles, the left one being slightly sinuous (Araújo 1961; Constantino 2002). Furthermore, *D. inusitatus*

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has dimorphic soldiers. The large (major) soldiers have the head protuberance pointed upwards, covering part of the mandibles and evident in lateral view, whereas the small (minor) soldiers have the protuberance only pointed upwards.

Here we describe a new *Dihoplotermes* species from the Amazon Region. All three castes (soldier, worker and imago after wing loss) are illustrated. *Dihoplotermes taurus* sp.nov. does not have dimorphic soldiers, lacks the protuberance on the postmentum and has a spine on the gizzard. We used both internal and external morphological characters to improve the characterization of the species.

MATERIAL AND METHODS

External characters of the soldier and imago castes and the external and internal characters of the worker caste were described. Terminology for the worker mandible follows Fontes (1987). The digestive tube terminology follows Noirot (1995; 2001). Internal characters of the imago were not analyzed, because there was only one specimen in our samples.

Morphometric characters follow the Roonwal's system (Roonwal 1970), when applicable, and are indicated in parenthesis: LH, head capsule length until the tip of the projection in soldiers and until the end of the labrum in workers and imagoes; LHM, head length in lateral view until the base of the mandibles (5); LM, mandible length (37); WH, maximum head width, including the eyes in the imago (17); LT, length of hind tibia (85); HH, head height excluding postmentum (21); WP, mean pronotum width (68); DE, maximum eye diameter, excluding ocular sclerite (49); LP, mean pronotum length.

Images were taken with a Leica DFC500 digital camera connected to a Leica MZ205 stereomicroscope linked to a computer with the Leica Application Suite software, which includes an Auto-Montage module. Drawings were made with Inkscape software and measurements were taken with a ocular micrometer. The distribution map of the species was made using SimpleMappr according to Shorthouse (2010).

RESULTS

Genus diagnosis

The soldiers of *Dihoplotermes taurus* and *Dihoplotermes inusitatus* have two anterolateral spines near the base of the mandibles, above the mandibular condyle; asymmetric snapping mandibles (Figure 1); asymmetrical labrum; and tibial spurs 3:2:2. Workers of both species have similar mandibles, with apical teeth distinctly larger than the first marginal teeth; right mandible without second marginal tooth; left mandible with third marginal tooth absent and molar tooth separated from first + second marginal by a small incision (Figure 2 D). The gut of both species has similarities regarding the gizzard, with a spine on the pulvillus (Figure



Figure 1. Soldier of *Dihoplotermes taurus*, sp. nov. (A). Head in lateral view (arrow points to the small step above the mandibles); (B). Head in dorsal view (arrow points to the spine in the anterolateral portion of the head capsule). This figure is in color in the electronic version. Scale bar = 1 mm

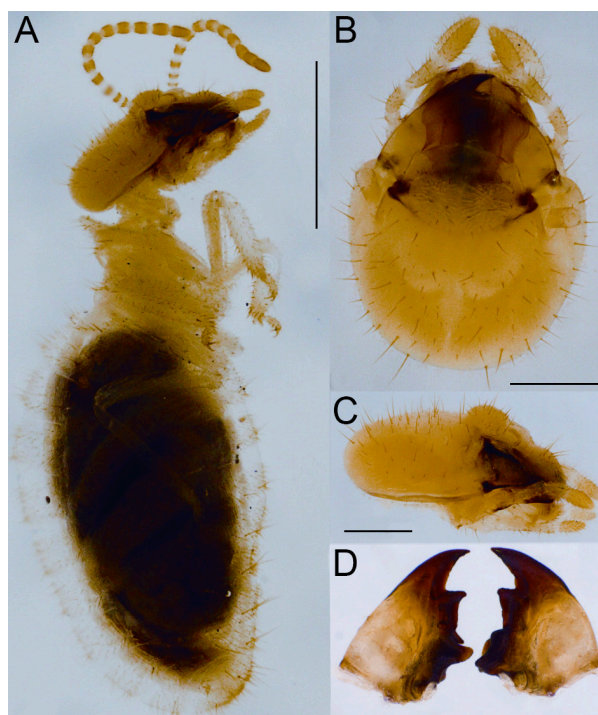


Figure 2. Worker of *Dihoplotermes taurus*, sp. nov. (A). Lateral view; (B). Head in dorsal view; (C). Head in lateral view; (D). Mandibles. This figure is in color in the electronic version. Scale bars: A = 1 mm; B = 0.3 mm; C = 0.3 mm; D = 0.1 mm.

7 B-C); presence of a malpighian nodule with two pairs of malpighian tubules inserted on the nodule (Figure 1 A); enteric valve with a longitudinal row of spines on one cushion (Figure 7 D-E).

Dihoplotermes taurus Azevedo, Dambros & Morais sp. nov.

Etymology. From the Latin “*taurus*”, which means “bull”, referring to the shape of the soldier’s head capsule and the behavior of the soldiers during collection, when they inclined their heads resembling a bull’s attack.

The species is registered in ZooBank at <<http://zoobank.org/NomenclaturalActs/F9E1FF88-4034-45B9-A369-A5A7056EF1B2>>

Material examined

Holotype. Soldier, in alcohol 80%, separated in microvial. Original label: “Brazil, Amazonas, Manaus, F. E. UFAM, L3 5500 (80-85), 2°38’00”S, 60°06’26”W. Coleta Manual 20/31-vii-2012. Azevedo. R. A. coll”. The holotype was deposited in the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia - INPA (INPA-ISO 000001).

Paratypes. Four soldiers and 15 workers with the same data as the holotype (INPA-ISO 000002); two soldiers, six workers and one imago with the following data: “Brazil, Amazonas, Manaus, F. E. UFAM, L4 5500 (180-185), 2°37’31”S, 60°06’22”W. Coleta Manual 20/31-vii-2012. Azevedo. R.A. coll” (INPA-ISO 000003); three soldiers and one worker with the following data: “Brazil, Amazonas, Manaus, F. E. UFAM, L3 5500 (130-135), 2°38’00”S, 60°06’26”W. Coleta Manual 20/31-vii-2012. Azevedo. R. A. coll” (INPA-ISO 000004), and five soldiers and nine workers with the following data: “Brazil, Amazonas, Manaus, F. E. UFAM, L4 5500 (130-135), 2°37’31”S, 60°06’22”W. Coleta Manual 20/31-vii-2012. Azevedo. R. A. coll” (INPA-ISO 000005). The specimens were deposited in the Invertebrate Collection of the Instituto Nacional de Pesquisas da Amazônia (INPA).

Description

Soldier (Figure 1 A-B). Head capsule yellowish, rectangular, with few bristles of distinct length distributed irregularly for almost the entire head extension. Head protuberance apex with a high density of bristles. One spine in each anterolateral part of the head capsule, near the base of the mandibles (Figure 1 A). Prominent projection on frontal side of the head capsule, covering part of the labrum and almost reaching the lateral margins in dorsal view. Concavity on the antero-inferior portion of the head projection, above the mandibles, forming a small step in lateral view, with two small projections on its margins, just above the antennal insertions. Postmentum narrower in the middle portion. Anterior portion of the postmentum slightly wider than the posterior portion, with a spine-like projection at the posterior edge of postmentum,

visible in lateral view. Mandibles asymmetrical and dark (Figure 1. B). Left mandible, in the first two-thirds of its proximal portion slightly curved towards the internal margin; distal portion slightly wider, but narrowing toward the apex, and curving to the right in a sickle shape, forming a small incision in which the right mandible fits. Right mandible approximately straight on the external margin, narrowing towards the apex, also with an incision in which the left mandible fits when closed. Apex pointed, slightly curved to the left. Symmetrical labrum, with seven to eight long bristles distributed usually in two rows. Apex slightly curved, with pointed anterior margins. Antennae with 14 articles. Antennomere I approximately three times longer than II < III = IV < V < VI = VII and VIII. The other antennomeres are equally sized. Pronotum, mesonotum, and metanotum with long and spaced bristles, distributed on the margins; pronotal anterior part with microscopic hairs. Abdomen with tergites and sternites covered by long bristles. Foretibia with few long setae irregularly distributed throughout its surface. Tibial spurs 3:2:2; with presence of a spine on the mesotibial distal region, close to the spurs, that could be mistaken for a third spur. Tibial spine is found in all castes. Measurements of soldiers are presented in Table 1.

Worker (Figure 2 A-D). Head capsule whitish, with bristles of different sizes, evenly spaced, except for the anterior margin. Fontanelle slightly conspicuous (Figure 2 B). Postclypeus slightly inflated, with few bristles. Labrum with density of bristles similar to the clypeus (Figure 2 C). Antennae with 14 articles. Antennomere I > II, and the following gradually increasing in length. Left mandible with apical tooth bigger and a little longer than first + second marginal; internal margin of the apical tooth slightly concave, with a small incision between first + second marginal and molar tooth. Molar prominence conspicuous, without ridges. Right mandible with apical tooth well developed, longer than the first marginal. Second marginal not noticeable. Molar plate slightly concave,

Table 1. Measurement of soldiers, workers and imago of *Dihoplotermes taurus* sp. nov (mm).

Measurement	Soldier		Worker		Imago
	range	mean	range	mean	
Head width	1.07 - 1.28	1.20	0.77 - 0.85	0.82	1.09
Head length with projection	2.07 - 2.51	2.32	–	–	–
Head length	1.53 - 2.00	1.86	0.98 - 1.10	1.05	1.16
Head height	0.76 - 0.89	0.84	0.38 - 0.44	0.39	0.51
Hind tibia length	0.94 - 1.07	1.02	0.80 - 0.85	0.82	1.25
Pronotum width	0.56 - 0.66	0.63	0.41 - 0.48	0.44	0.90
Pronotum length	–	–	–	–	0.52
Mandible length	1.71 - 2.05	1.93	–	–	–
Eye diameter	–	–	–	–	0.26
Number of specimens	18		17		1

without ridges (Figure 2 D). Microscopic hairs on the pronotal anterior portion, long bristles on the anterior margin of pro-, meso- and metanotum. Abdomen transparent, tergites and sternites densely covered by short bristles and by a row of long bristles on the posterior portion of each sternite (Figure 2 A). Foretibiae slightly widened with many bristles of distinct sizes distributed throughout its surface.

Digestive tube (Figures 3 - 4). Soldiers and workers have similar digestive tube configuration. Gut forming a dense mass, slightly longer than wide. Proximal portion spiral-shaped, posterior to the crop in dorsal view (Figure 3 A). Crop enlarged, tapering towards the gizzard in which it connects. Gizzard small, columnar belt with six folds of the first and

second order (Figure 4 B); first order pulvillus with a short spine in the medial region (Figure 4 C); columnar belt absent; gizzard connects to the anterolateral region of the mesenteron, which is slightly widened (Figure 3 D). Malpighian nodule visible on the mesenteric tongue; mesenteric tongue short and only visible when dissected and under the microscope; two pairs of malpighian tubules inserted at the same point of the nodule (Figure 4 A). In ventral view: connection of mesenteron with the ileum occurs at the same height of the connection of the crop with the gizzard (Figure 3 C). Ileum tubular, slender and short. Ileum starts at the left side of the anterior region and ends in the posterior left side of the posterior region, where it connects with the paunch. Enteric valve with six cushions of diverse shape and size (Figure 4 D); five cushions with few short spines distally; one cushion with a row of longitudinal spines distally (Figure 4 E). Paunch subdivided into two parts in ventral view; one part is smaller and tubular shaped and connected with the ileum. The second part is larger and wider, tapering towards the apex, partially covered by the colon in dorsal view. Paunch with a small, narrowing and slightly curved in the area near the colon. Colon widened, always wider than the mesenteron. In dorsal

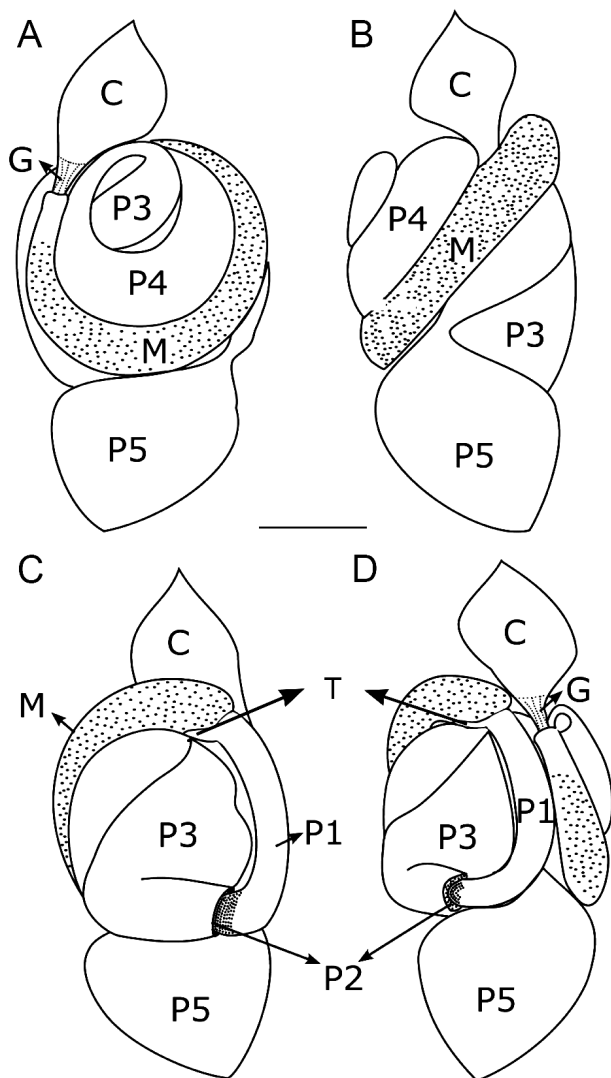


Figure 3. Digestive tube of the worker of *Dihoplotermes taurus*, sp. nov. (A) Ventral view; (B) Right view; (C) Ventral view; (D) Left view. C, crop; G, gizzard; M, mesenteron; P1, first proctodeal segment; P2, enteric valve; P3, paunch; P4, colon; P5, rectum; T, mesenteric tongue (enlarged for better viewing). Scale bar = 0.5 mm.

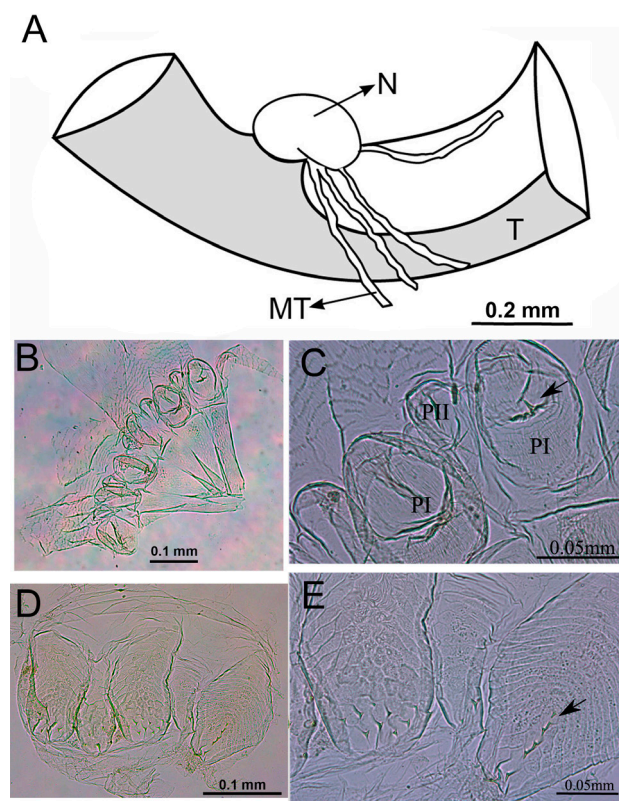


Figure 4. Digestive tube of the worker of *Dihoplotermes taurus*, sp. nov. (A) Insertion of Malpighi tubules; (B) Gizzard; (C) PI, pulvilli I; PII, pulvilli II (arrow points to a spine on the gizzard); (D) Enteric valve; (E) Cushions of the enteric valve (arrow points to the spine). N, malpighian nodule; MT, malpighi tubules; T, mesenteric tongue. This figure is in color in the electronic version.

view, U-shaped above the mesenteron. Colon involves partially the paunch final portion, forming a curve to the right side that follows until it connects with the rectum through a slight muscular constriction. Rectum very broad, approximately of the same width of the gut (Figure 3 B). Measurements of workers are presented in Table 1.

Imago: (Figures 5 A-D). Cephalic capsule brown, densely covered with several short bristles and few long bristles; fontanelle conspicuous, drop-shaped, forming a small depression on top of the head; ocelli small, semicircular and prominent. Eyes of medium size, rounded and protuberant. Postclypeus small, yellowish brown, almost trapezoidal and slightly inflated, with many bristles of different sizes distributed throughout its surface. Labrum with many bristles, with its widest part approximately with the same width of the postclypeus (Figure 5 A-B). In both antennae the last articles were broken: Antennomere I wider and approximately three times longer than II > III = IV to VII. The following antennomeres progressively increase in length. Pronotum light brown, covered with bristles, except in its middle part and just below the anterior lobe until near the margins; pronotum slightly narrower than the head; pronotal anterior part with microscopic hairs, median line weak, but visible in the anterior

margin. Anterior portion of meso- and metanotum dark yellow and posterior portion dark brown. Anterior portions narrowing towards posterior portions, reaching the apex of the wing scales; anterior portions partially covered by the wing scales; posterior margins bilobate, mesonotal posterior margin semicircular shaped and metanotal posterior margin V-shaped. Bristles on dorsal surface (Figure 5 C). Tergites with the same color as the pronotum, with many small bristles and some long bristles. Sternites light brown on the lateral margins and dark yellow near the median line. A row of long bristles on the posterior margins of each sternite. The coxae first pair with small protuberances on the anterior proximal surface (Figure 5 D). Tibia long and thin. Only one imago was found and it was preserved. Therefore, mandibles were not extracted. Measurements of the imago are presented in Table 1.

Distribution and habitat. The colonies of *Dihoplotermes taurus* were found at the Experimental Farm of Universidade Federal do Amazonas (UFAM), located at km 38 of the BR-174 highway, which connects the Brazilian cities of Manaus (Amazonas state) and Boa Vista (Roraima state) (Figure 6), a rainforest area that covers almost 3.000 ha. The climate is equatorial, warm and humid, with high rainfall during the rainy season (Kotteck *et al.* 2006). The colonies were collected in the subsoil. Conspicuous nests were not found and the sampled individuals were collected in the soil during digging. We suppose that nests are located underground, diffuse in the soil.

Comparison with similar taxa

The soldiers of *D. taurus* sp. nov. differ from those of *D. inusitatus* by having a small projection in form of a spine with blunt apex on the postmentum, which is a unique characteristic of this species. However, workers of *D. taurus* share similarities in the gut with workers of *D. inusitatus*, such as the gizzard, malpighian tubules and enteric valve (Figures 4 and 7). Regarding phylogenetic and morphological differences between *Palmitermes* and *Dihoplotermes* (Hellemans *et al.* 2017), a smaller projection in the same region is also present in *Palmitermes* (Hellemans *et al.* 2017). However, both soldiers of *Dihoplotermes* have a lateral spine on each side of the head at the mandible base and a conspicuous frontal protuberance on the postmentum. In the non-dimorphic soldiers of *D. taurus* this protuberance is not projected forward as in the major soldiers of *D. inusitatus*. The frontal prominence observed in *D. taurus* sp. nov. is also present in *Palmitermes* and *Termes*. In our samples of *D. taurus* sp. nov. in multiple colonies, only one type of soldier was found, which might suggest that the soldier's caste of this species is monomorphic, whereas soldiers of *D. inusitatus* are dimorphic. The spine on the gizzard's puvillar belt is a unique characteristic of Neotropical termites.

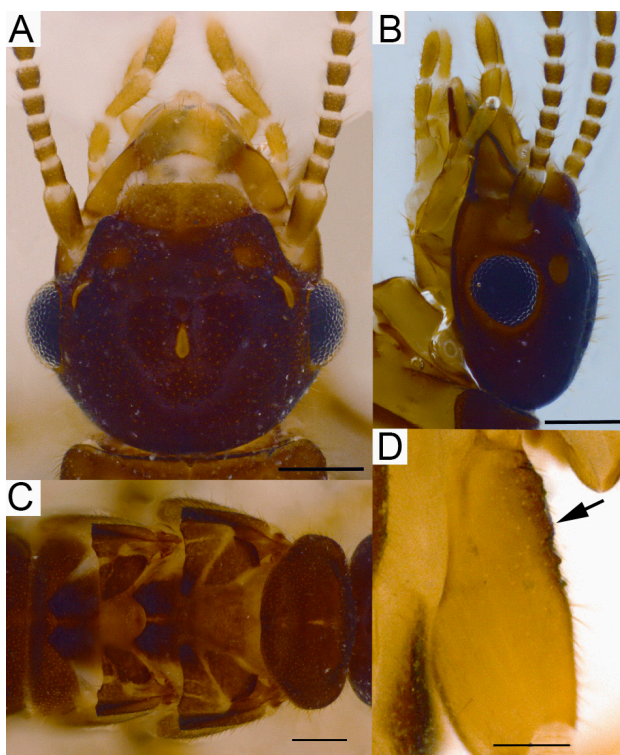


Figure 5. Imago of *Dihoplotermes taurus* sp. nov. (A) Head in dorsal view; (B) Head in lateral view; (C) Pro-, meso- and metanotum in dorsal view; (D) Procoxae in lateral view (arrow points to the anterior protuberances). This figure is in color in the electronic version. Scale bars: A-C = 0.3 mm; D = 0.15 mm.

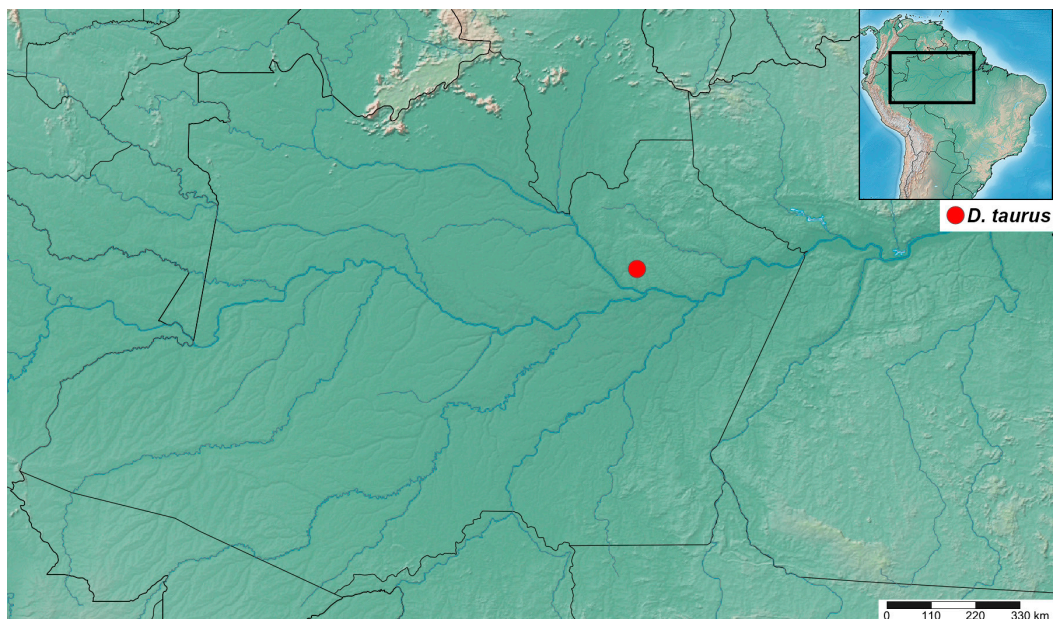


Figure 6. Location of the type locality of *Dihoplotermes taurus* sp. nov. in the central Brazilian Amazon. This figure is in color in the electronic version.

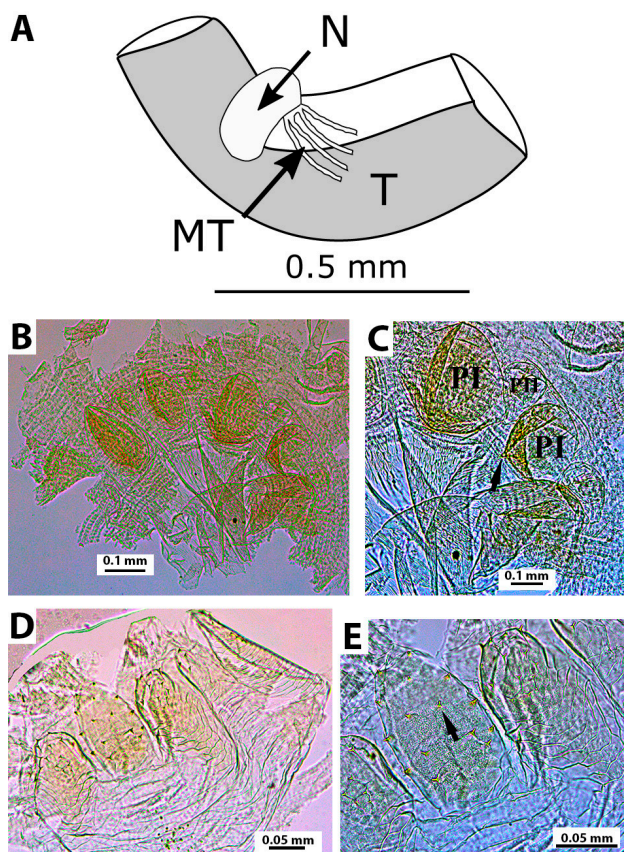


Figure 7. Digestive tube of the worker of *Dihoplotermes inusitatus*, sp. nov. (A) Insertion of malpighian tubules; (B) Gizzard; (C) PI, pulvilli I; PIL, pulvilli II (arrow points to a spine on the gizzard); (D) Enteric valve; (E) Cushions of the enteric valve (arrow points to the spine). N, malpighian nodule; MT, malpighian tubules; T, mesenteric tongue. This figure is in color in the electronic version.

DISCUSSION

Recent phylogenies suggest that the *Dihoplotermes* and *Spinitermes* genera represent a sister clade to *Cavitermes* and *Palmitermes*, both in the *Termes*-group (Hellemans *et al.* 2017). All species of these four genera are Neotropical and form the *Cavitermes* lineage, supported mainly by mitochondrial genomes and chemical profiles of cuticular hydrocarbons. Although *Divinotermes* Carrijo & Canello was not included in this analysis, it shares noteworthy similarities with some genera of this lineage, i.e. the imago of *Divinotermes* with the imago of *Cavitermes* and soldiers of *Divinotermes* with soldiers of *Spinitermes robustus* (Snyder, 1926), as pointed out by Carrijo and Canello (2011). Some genera of the *Cavitermes* lineage share traits of the mandibles of workers, as in *Palmitermes* and *Cavitermes*. *Dihoplotermes* is the most morphologically distinct genus in this group due to the traits of mandibles of workers and the asymmetry of the mandibles of soldiers. Asymmetrical mandibles evolved four times, which makes them plastic and more susceptible to environmental pressures and adaptive restrictions than to shared ancestry, which enhances the idea that only morphological traits may mask phylogenetic relationships (Inward *et al.* 2007). Although the gizzard has a thorn, which makes *D. taurus* distinct from other genera, the enteric valve is a remarkable character that notably places *D. taurus* near *Palmitermes impostor* Hellemans and Roisin, as both species have asymmetrical lobules, distinct from *Cavitermes tuberosus* (Emerson) and *Termes fatalis* Linnaeus (Hellemans *et al.* 2017). The morphological traits of *D. taurus* sp. nov., specially in the worker mandible, are highly similar to those of *D. inusitatus*, the type-species of the genus (personal

observation, see also Araujo 1961). The internal structures of the digestive system, such as the gizzard and enteric valve, have been used for phylogenetic analyses (Hellemans *et al.* 2017). However, these structures were not described in *D. inusitatus*, the type-species of the genus.

As suggested by one anonymous reviewer, Araújo (1961) made one mistake describing the third marginal tooth in the left mandible of workers. As seen in Fontes (1987), whenever the third marginal is present, it is also visible in front of the molar tooth and never hidden beneath the molar prominence. Hence, we changed the diagnosis of *Dihoplotermes* replacing the third marginal by the molar tooth.

CONCLUSIONS

The description of *D. taurus* n. sp. and the recent phylogenetic studies of the Termitinae (Bourguignon *et al.* 2017) and *Termes*-group (Hellemans *et al.* 2017) allowed us to compare these groups and to include the new species within the *Termes*-group. Regarding the morphological similarities among the *Dihoplotermes* species, a review of all species in the genus and the *Termes*-group will be necessary to determine the phylogenetic positioning of the described species.

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